# 7 Steps of LTMO

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Groundwater Services, Inc.


LTMO

# Credits

**Roadmap for Long-Term Monitoring Optimization**

**Contributors:**

**Carolyn Nobel, PARSONS**

**John Anthony, Mitertek**

**Dave Becker, USACE**

**Demonstration of Two Long-Term Monitoring Optimization Methods**

**USEPA Office of Superfund Remediation and Technology Innovation**

**Guidance for Monitoring at Hazardous Waste Sites**

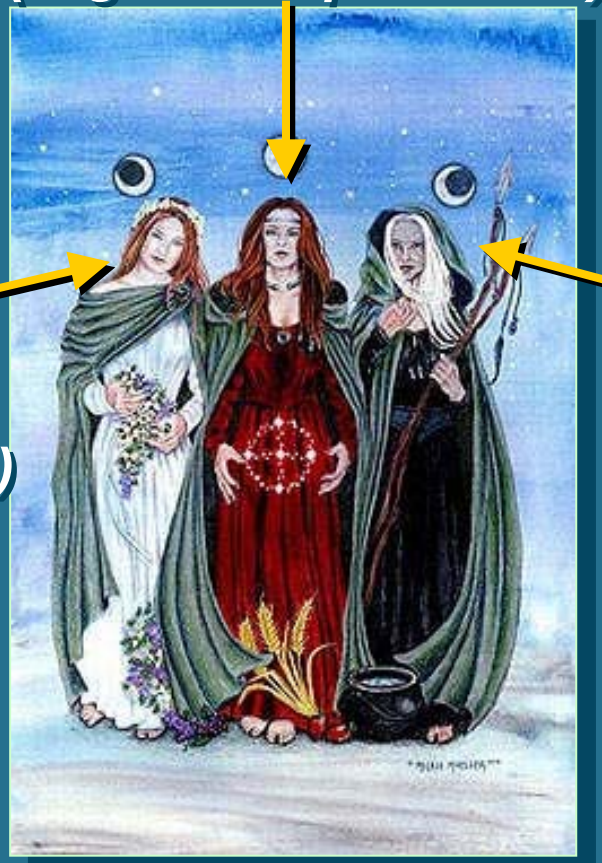
**OSWER Directive No. 9355.4-28**

# Goals

- *Introduce language,concepts and methods central to LTMO*
- *Define steps common to LTMO analyses*
- *Determine if and when optimization is appropriate for your program*
- *Introduce methods available and appropriate for your program*

# Phases of a Site

**Remedy Selection/Monitoring**
***(engineered processes)***



**Site Characterization**
***(uncertainty reduction)***

**Long-Term Monitoring**
***(natural processes)***



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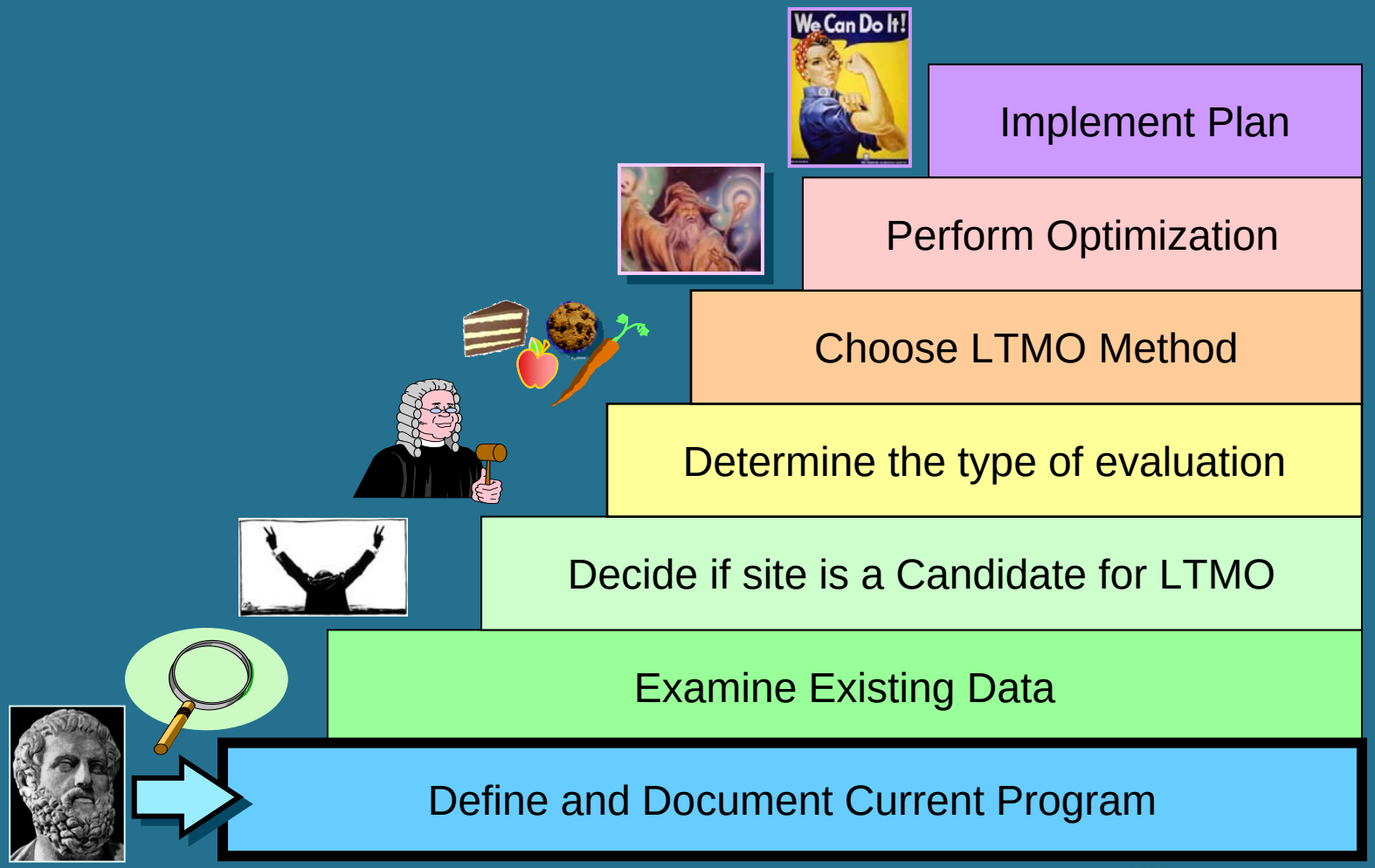
# 7 Steps of LTMO



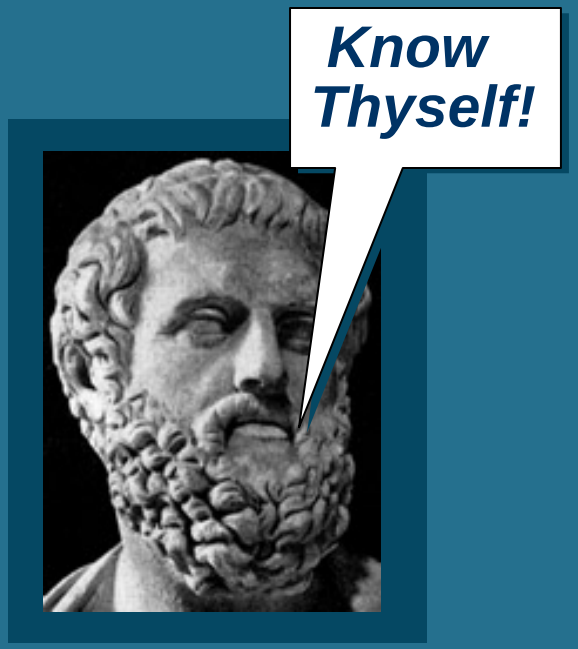



LTMO

# Current Monitoring Program

## Components of your Current Monitoring Program

- Conceptual Site Model
- Objectives
- Monitoring Conceptual Model
- Design of Monitoring Plan
- Management Decision Rules



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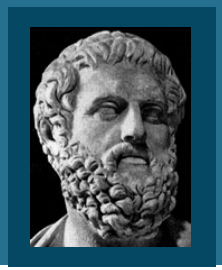
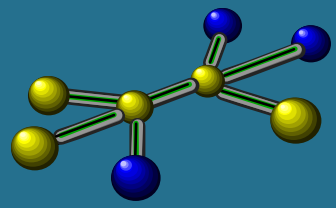
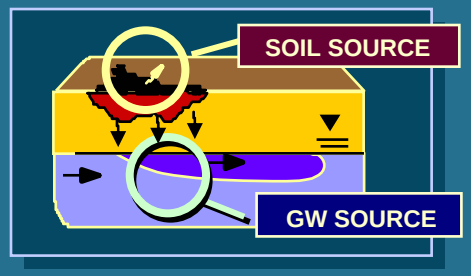
# Current Monitoring Program

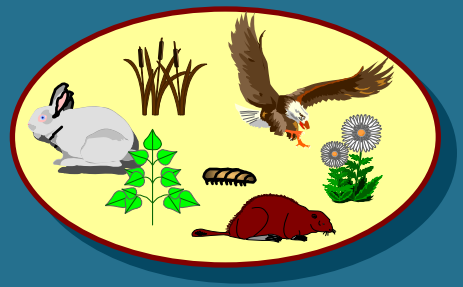


## Conceptual Site Model



- Sources
- Analytes
- Matrices
- Potential receptors
- Regulatory framework
- Property use/community issues
- Assumptions/Uncertainties





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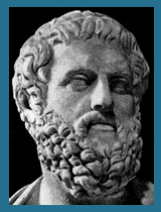
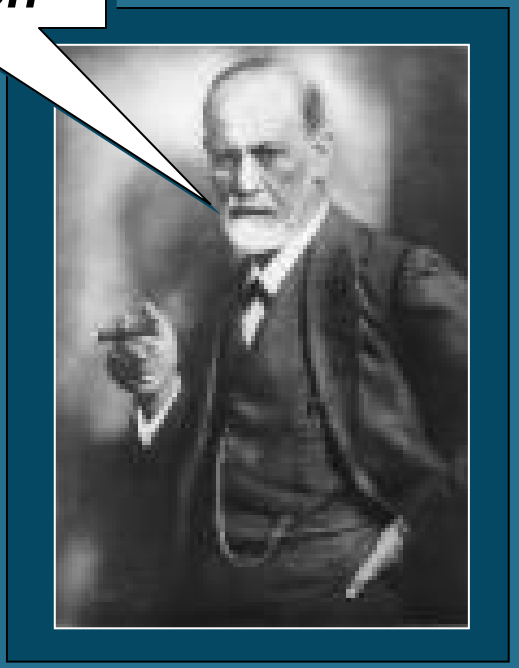
# Current Monitoring Program



## Objectives

***Understand your motivation***



- Site Characterization Phase
  - Determine/delineate COCs
  - Quantify COCs
  - Characterize subsurface

(USEPA, 2004)



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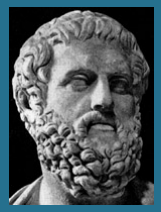
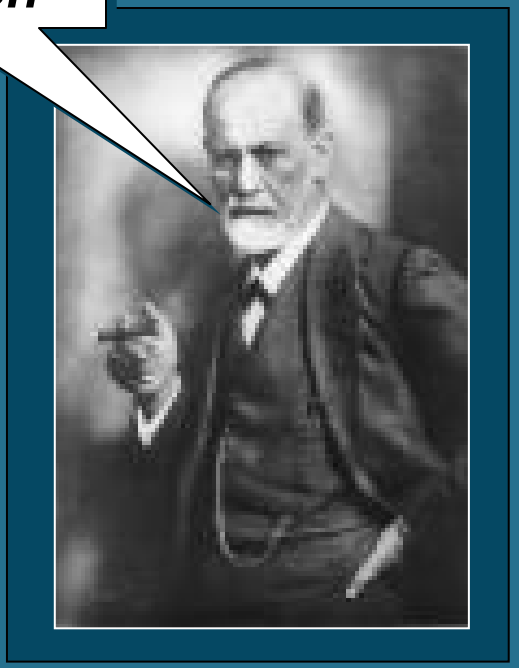
# Current Monitoring Program



## Objectives

- Monitoring Objectives
  - Evaluate remedy effectiveness
  - Evaluate contaminant migration
  - Evaluate changes in natural resource
  - Comply with regulatory requirements

***Understand your motivation***



(USEPA, 2004)



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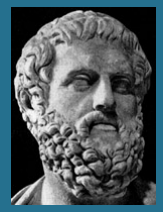
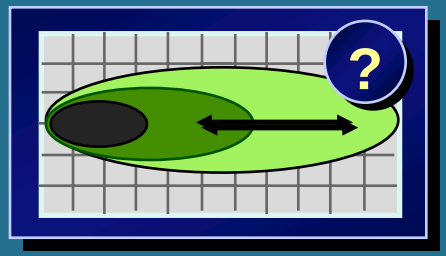
# Current Monitoring Program



## Objectives

- *Temporal state* of constituent concentrations
  - Single location over time
  - In or near the remedial zone to monitor remedial performance

- *Spatial extent* of contaminant distribution
  - Migration of constituents
  - Potential receptors



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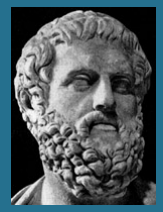

## Monitoring Conceptual Model

*Identifies the relationship between site activity and outcome.*

*(Hint: Its Science.)*

*Refine Objectives to be consistent with Monitoring Conceptual Model*



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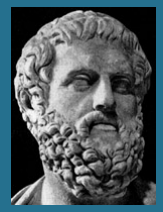
# Current Monitoring Program



## Monitoring Conceptual Model

- Monitoring hypothesis
  - *COC concentrations are changing with time.*
- Monitoring question
  - What is changing?
  - How fast is it changing?
  - Where is it changing?



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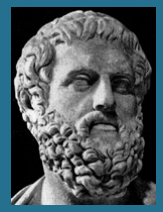
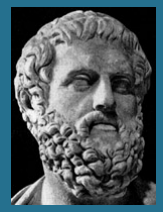
# Current Monitoring Program



## Monitoring Conceptual Model

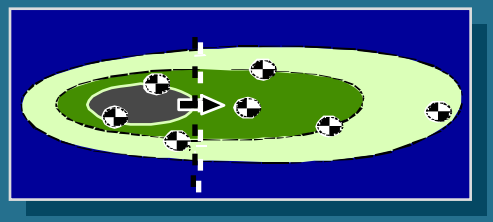
- Collect data to evaluate hypothesis
- Hypothesis testing
  - Analyze data using appropriate methods/statistics
- Scientific Management Decision Point
  - Document decision with data/weight of evidence.

# Current Monitoring Program



## Design of Current Monitoring Program

- What data have been collected and why?
  - Analytical methods
  - Detection limits
- How are data collected?
- Where have data been collected?
- How have data been analyzed?
- How is the dataset managed?
- How much does this cost?
- Who is paying for this?





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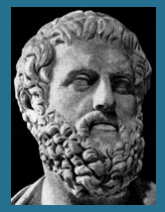
# Current Monitoring Program



## Management Decision Rules

- Identify actions taken and criteria for actions taken.
- Have monitoring objectives been met?
- How has the monitoring program been altered through time and why.



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# Current Monitoring Program

## Regulatory/Community Issues

- Is the site moving to a different regulatory status/phase?
- What are the long-term goals of property re-use?
- What is my current relationship with stakeholders?
- How can LTMO improve the current stakeholder relationship/property re-use?



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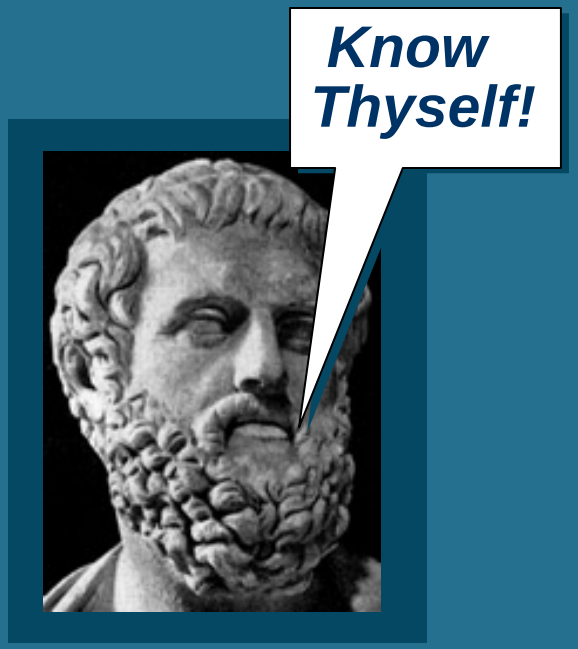
# Current Monitoring Program

## Summary

- Conceptual Site Model
- Objectives
- Monitoring Conceptual Model
- Design of Monitoring Plan
- Management Decision Rules



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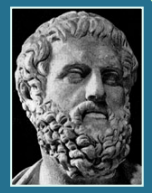
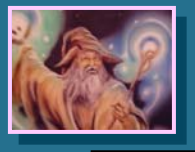
# 7 Steps of LTMO






Define and Document Current Program

Examine Existing Data

Decide if site is a Candidate for LTMO

Determine the type of evaluation

Choose LTMO Method

Perform Optimization

Implement Plan

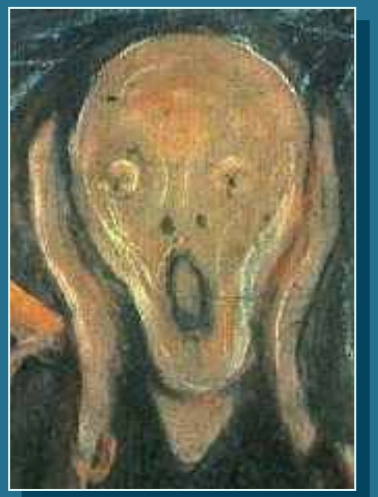


LTMO

# Examine Existing Data

## Acquire and Process Data

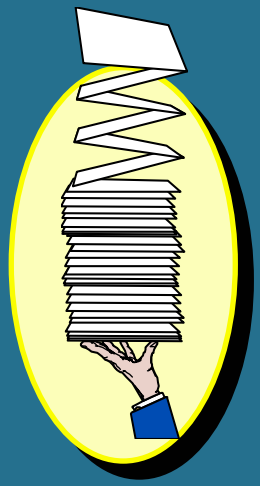
- Data acquisition and availability
- Data format
- Data reduction



# Examine Existing Data

## Checklist *(Important stuff)*

- Site description/history
  - RFI, CSM, ROD
- Historical COC data
  - Investigation and monitoring reports
- Site hydrology/geology
  - RFI, CSM





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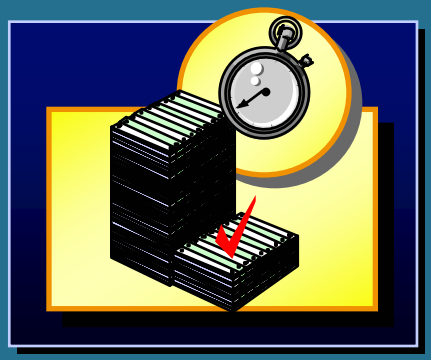
# Examine Existing Data

## Checklist *(Important stuff)*

- Description of current monitoring program
- Location coordinates (survey, GPS)
  - Wells and Property boundaries
  - Sources and Receptors
  - Surface water, Roads





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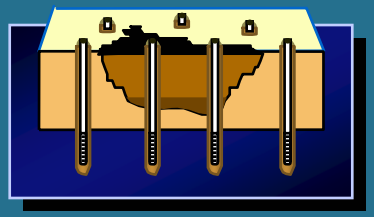
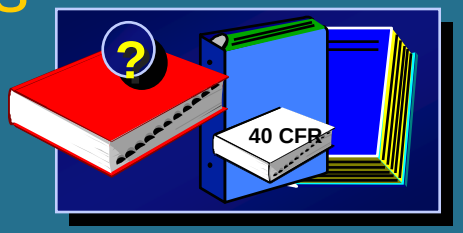
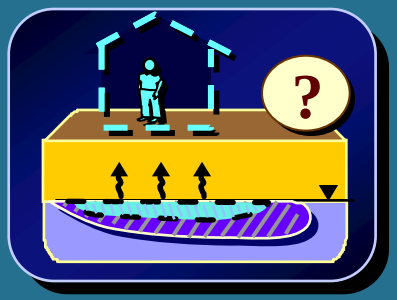
# Examine Existing Data

## Checklist *(Important stuff)*



- Well construction/completion intervals
  - Construction diagrams
- Regulatory context, cleanup goals
  - Risk based goals
- Location of potential receptors
  - Risk assessments



# Examine Existing Data

## Checklist *(Useful stuff)*

- Logistical and policy issues
  - – Stakeholders, property owners
- Site features
  - – Aerials, AutoCad, GIS base maps
- Historic hydrology
- Geochemistry
- Costs and budgets

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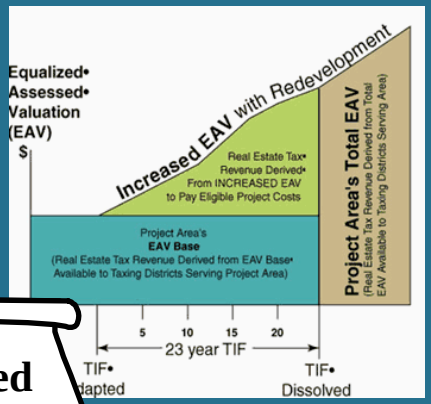
# Examine Existing Data

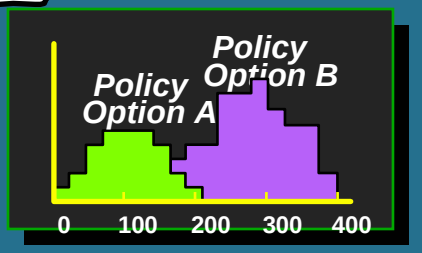
## Checklist

*More important than you think*

- Current property use
- Future property use
- Pending sale/re-use/litigation








Cost Distributions

# Examine Existing Data

## Data Format

*Clean-up your data!*

- Hunt, gather, beg, create
- Convert to electronic files
- Database format
- Identify spurious points/artifacts
- Data deficiencies?

# Examine Existing Data

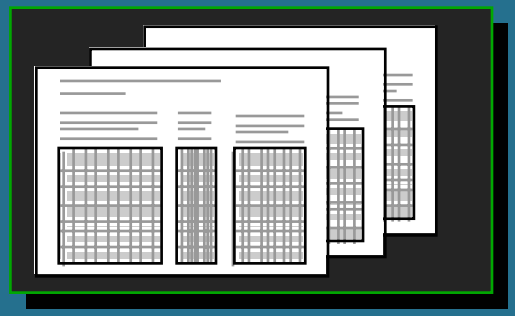
## Data Reduction

- How are data flags handled?
  - J flags
  - Non-detect results
- How are duplicates interpreted?
- Dilution factors
- Data consolidation
- Missing detection limits?

# Examine Existing Data

## Summary

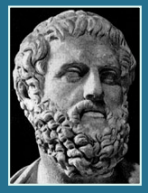

- Gather Reports
- Organize Data (Electronic format)
- Review Data
- Data Reduction/Consolidation
- Expensive ($$$)





LTMO

# 7 Steps of LTMO



Implement Plan

Perform Optimization

Choose LTMO Method

Determine the type of evaluation

Decide if site is a Candidate for LTMO

Examine Existing Data

Define and Document Current Program

# Candidates for LTMO

## Is my site a Candidate?

- Is the site investigation complete?
- Minimum Data requirements fulfilled?
- Remediation status consensus?
- Budget and labor considerations?

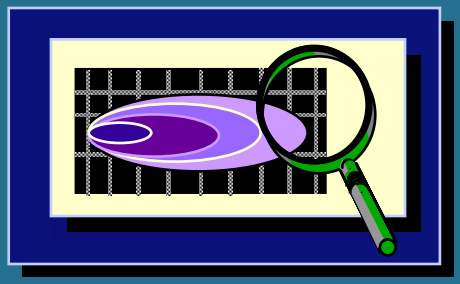



LTMO

# Candidates for LTMO

## Is my site a Candidate?

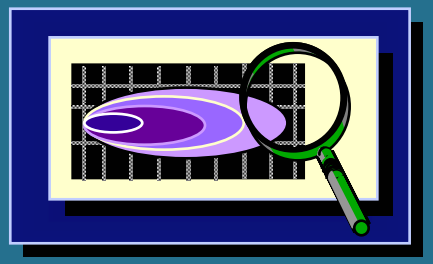
- *Is the site investigation complete?*
  - Source identified?
  - Plume delineated?
    - Vertical
    - Horizontal



# Candidates for LTMO

## Is my site a Candidate?

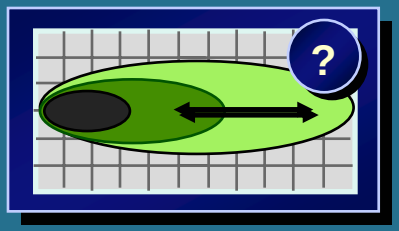
- *Is the site investigation complete?*
  - COC's identified?
  - Hydrology known/modeling complete?
  - Conceptual Site Model complete?
  - Receptors Identified

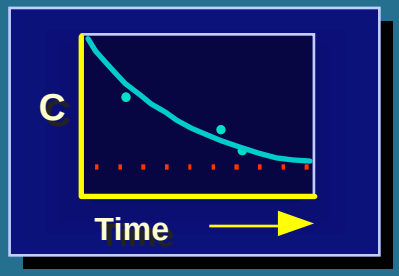


# Candidates for LTMO

## Is my site a Candidate?

- *Data requirements fulfilled?* ✓
  - Temporal: > 4 to 6 sample events, 8 events suggested for significance for some statistical tests





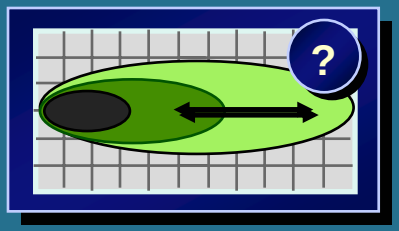


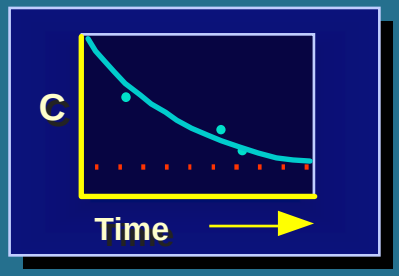
LTMO

# Candidates for LTMO

## Is my site a Candidate?

- *Data requirements fulfilled?* ✓
  - Spatial: > 6 to 15 monitoring locations
  - Housekeeping: data organized and complete

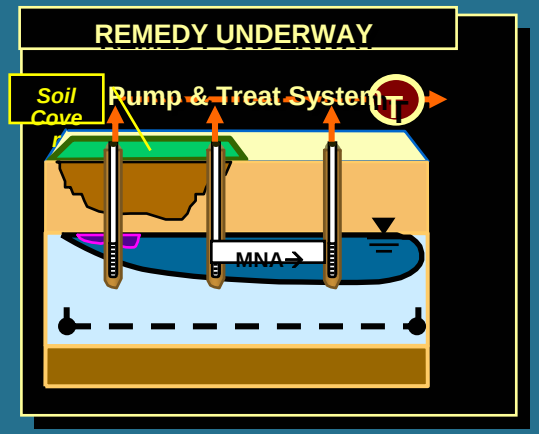



# Candidates for LTMO

## Is my site a Candidate?

- *Remediation status confirmed?*
  - Stakeholders agree
  - Intensive remedies completed
    - No further construction
  - Pump and Treat or Natural Attenuation remedies on-going



# Candidates for LTMO

## Things to consider

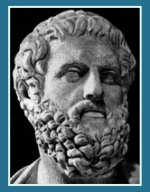
- Effort and budget to perform optimization
- Technical capabilities of team
- Resistance to implementation
- Potential benefits vs. cost
- Deficiencies in current monitoring program
- Likelihood of further remediation

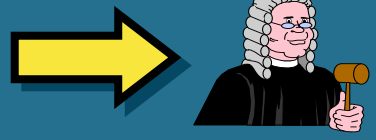
# Candidates for LTMO

## Summary

- The site investigation is complete.
- Minimum Data requirements fulfilled.
- Remediation status consensus.
- Budget and labor adequate.

# 7 Steps of LTMO





Implement Plan

Perform Optimization

Choose LTMO Method

Determine the type of evaluation

Decide if site is a Candidate for LTMO

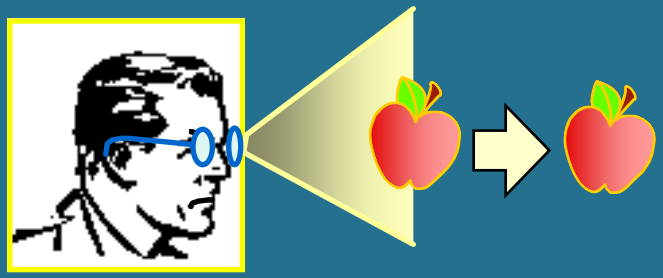
Examine Existing Data

Define and Document Current Program

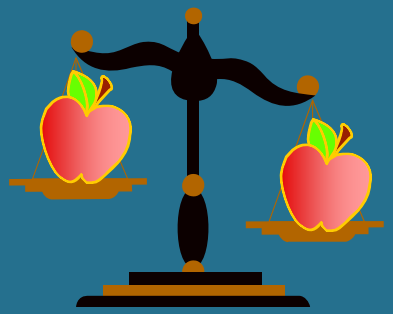
# Evaluation Type

## Evaluation Strategies

***Qualitative***



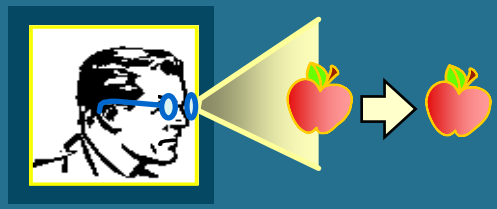
***Quantitative***

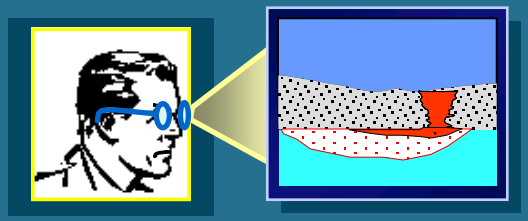


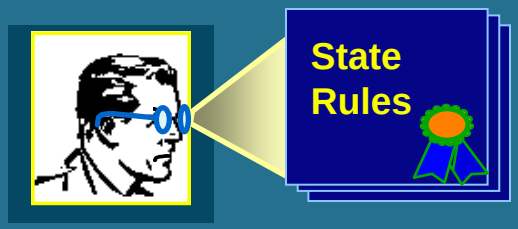
# Evaluation Type

## Evaluation Strategies

*Qualitative evaluations based on professional judgment, intimate knowledge of site, decision rules, heuristic methods*







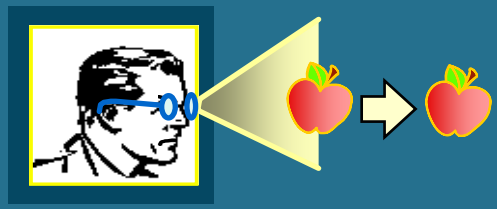


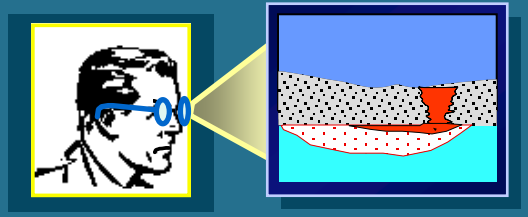

LTMO

# Evaluation Type

## Evaluation Strategies

- Geology/Hydrology
- Fate and transport of COCs
- Monitoring objectives, migration pathways and receptors
- History and regulatory framework







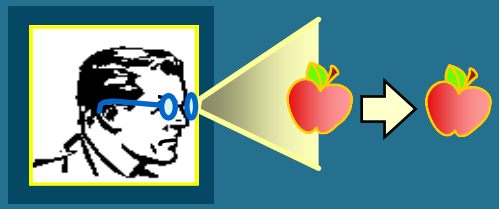

LTMO

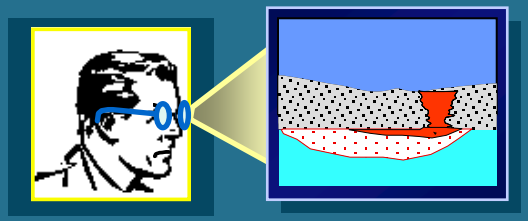
# Evaluation Type

## Evaluation Strategies

Decision Logic

- Monitoring Well important for:
  - Vertical/horizontal delineation
  - Background water quality
  - Proximity to source/receptor
  - Regulatory compliance







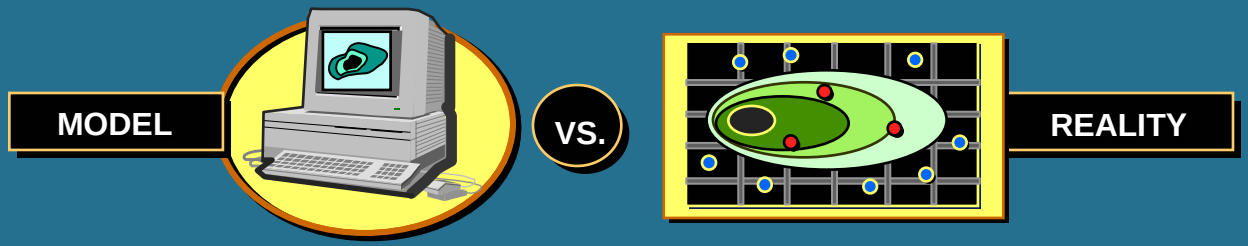

LTMO

# Evaluation Type

## Good News

***Qualitative Evaluations***

- Context specific, multiple factors, includes intuitive, less tangible information
- Good for including regulatory and community issues






LTMO

# Evaluation Type

## Less-Good News

***Qualitative Evaluations***

- Problem if stakeholders do not agree
- Consultant dependent
- May not reveal data inadequacies, may carry over biases
- Specific personnel required




LTMO

# Evaluation Type

## Evaluation Strategies

*Quantitative evaluations based on statistical, mathematical, modeling or empirical evidence*



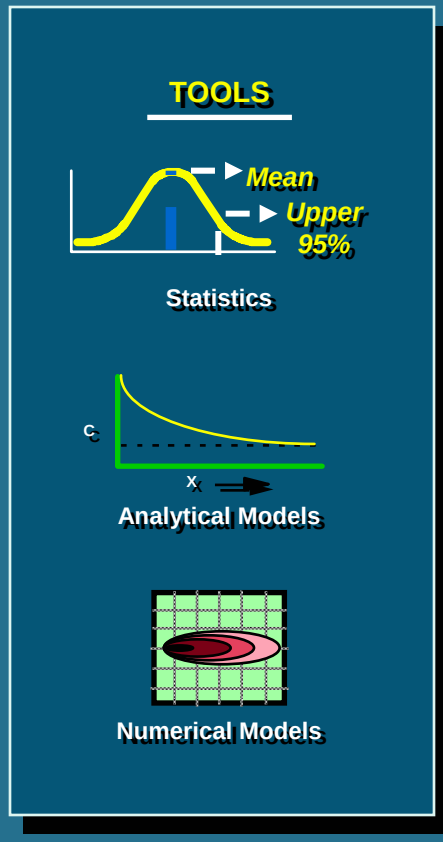
LTMO

# Evaluation Type

## Evaluation Strategies

*Quantitative Evaluations*

- Trend analysis
- Geo-statistics
- Information Weighting

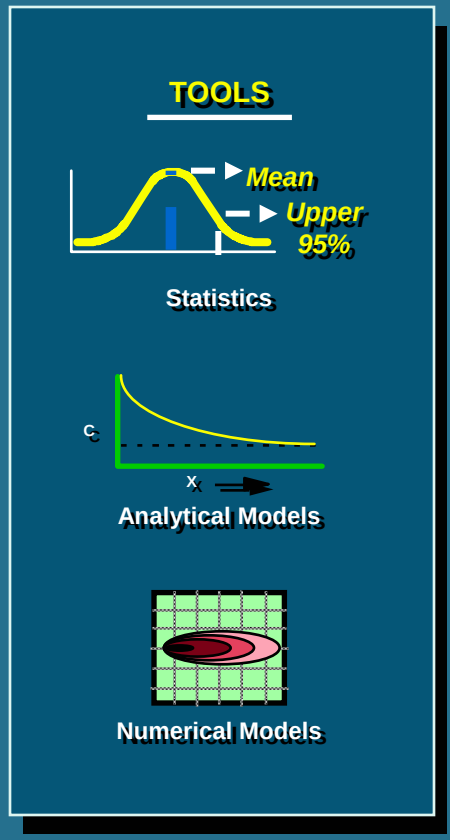


# Evaluation Type

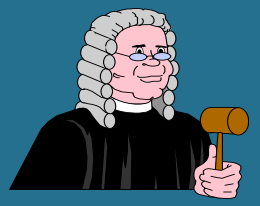
## Evaluation Strategies

*Quantitative Evaluations*

- Modeling studies and simulations
  - Projected concentrations
  - Projected attenuation
- Algorithms for temporal sampling



# Evaluation Type



## Good News

*Quantitative Evaluations*

- Bring stakeholders together with quantitative analysis
- Specific justification for action
- Can highlight data deficiencies, mis-interpretations, uncertainty.

# Evaluation Type

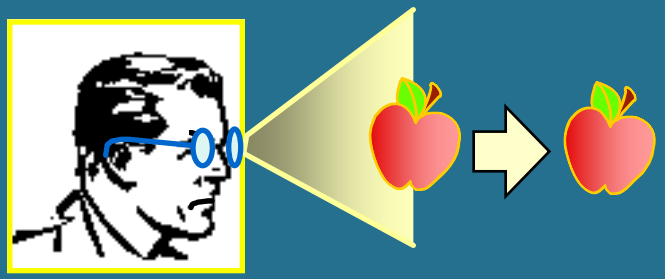
## Less-Good News

*Quantitative Evaluations*

- More rigorous data requirements
- Cost
- Time and effort
- Technical expertise
- Junk in → Junk out

# Evaluation Type

## Evaluation Strategies

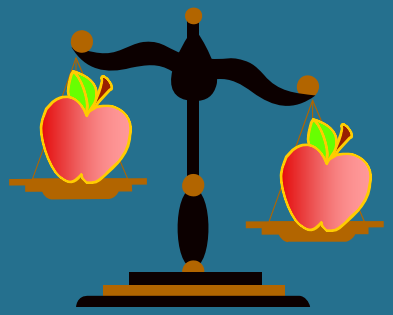


*Qualitative*

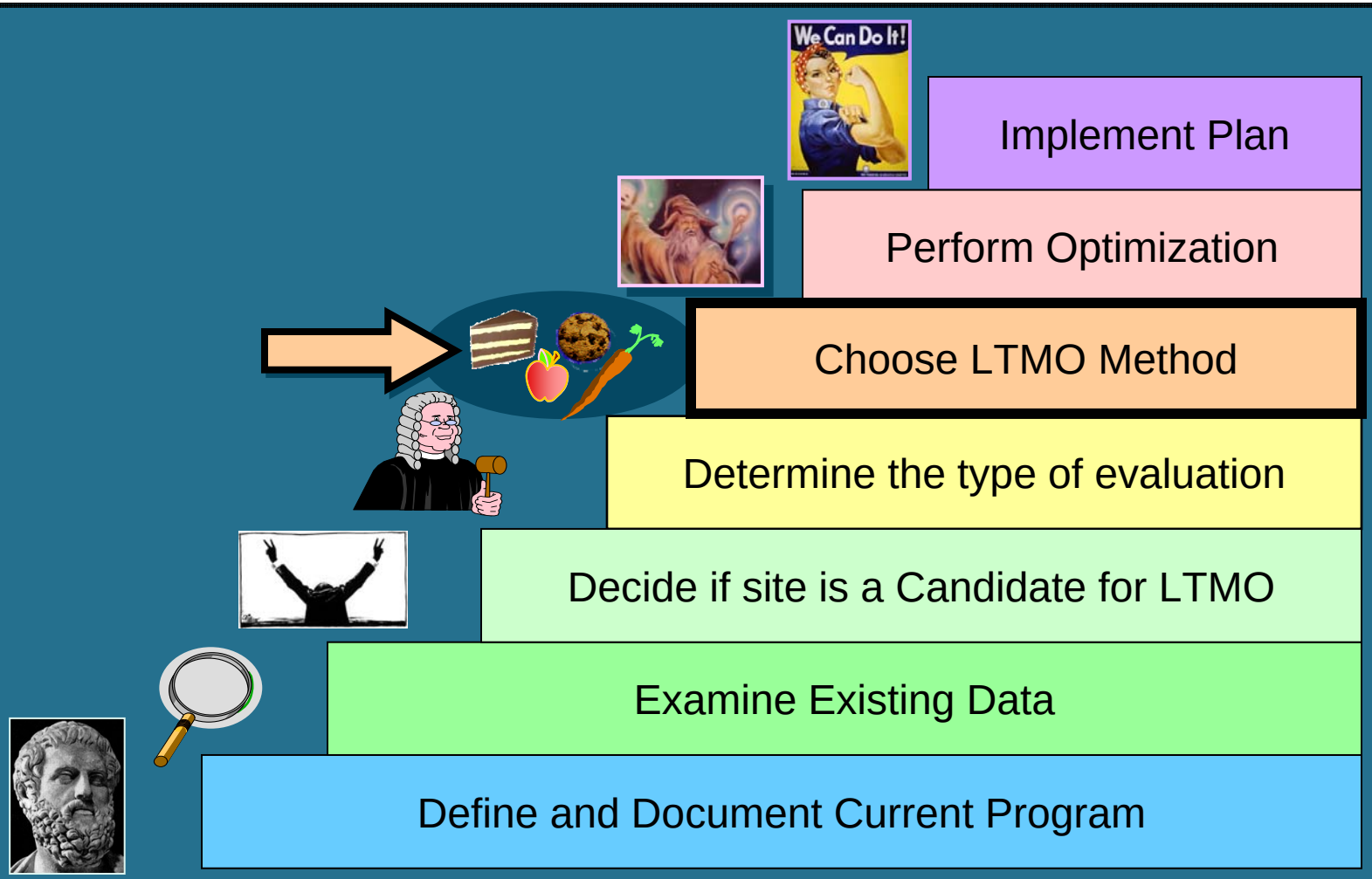
*Quantitative*

*(Both needed)*

*Independent Review?*



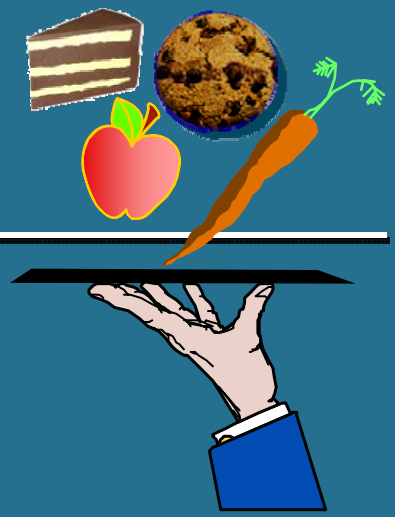
# 7 Steps of LTMO






LTMO

# Choose LTMO Method



## LTMO Methods

*Choice should reflect:*

- Balance qualitative and quantitative methods
- Time, effort, skill set and cost
- Stakeholder consensus
- Appropriate to size, complexity, dataset and risk of site

# Choose LTMO Method

## LTMO Guidance

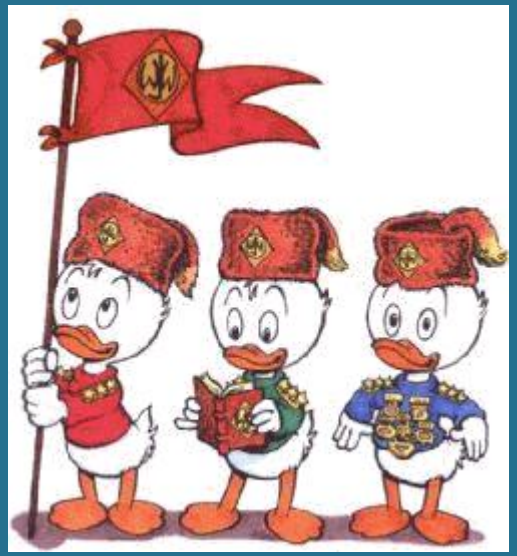
*Guidance Documents:*

- Naval Facilities Engineering Service Center
- AFCEE
- DOD
- USEPA

# Choose LTMO Method

## LTMO Team

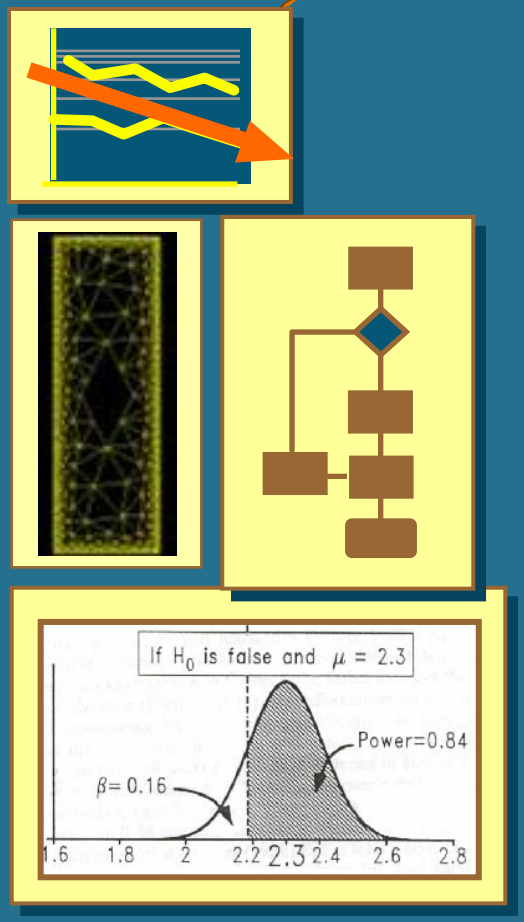
- Geology/hydrology
- Statistical
- Data management
- Regulatory



# Choose LTMO Method

## LTMO Tools

- Decision logic
- Statistical trend analysis
- Statistical significance testing
- Interpolation
- Mathematical Optimization





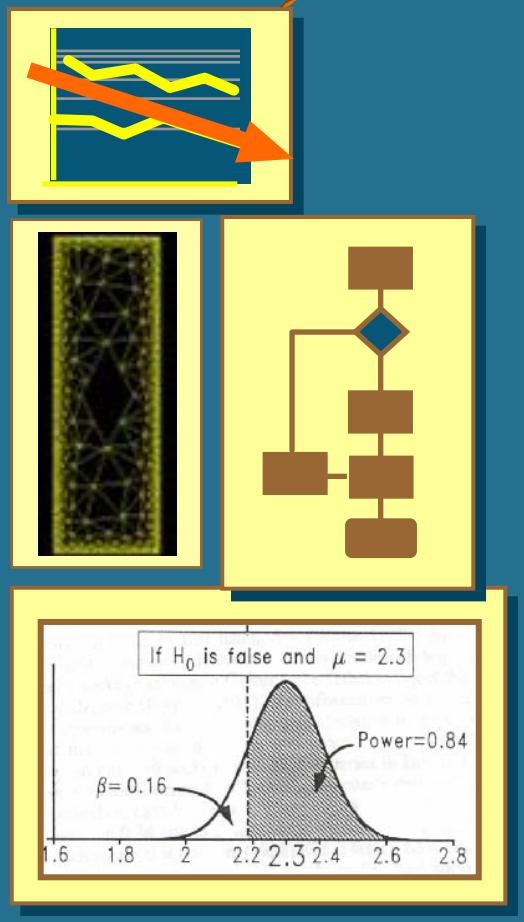

LTMO

# Choose LTMO Method

## LTMO Tools

- Decision logic

  “If the concentration is increasing, then sample semi-annually.”



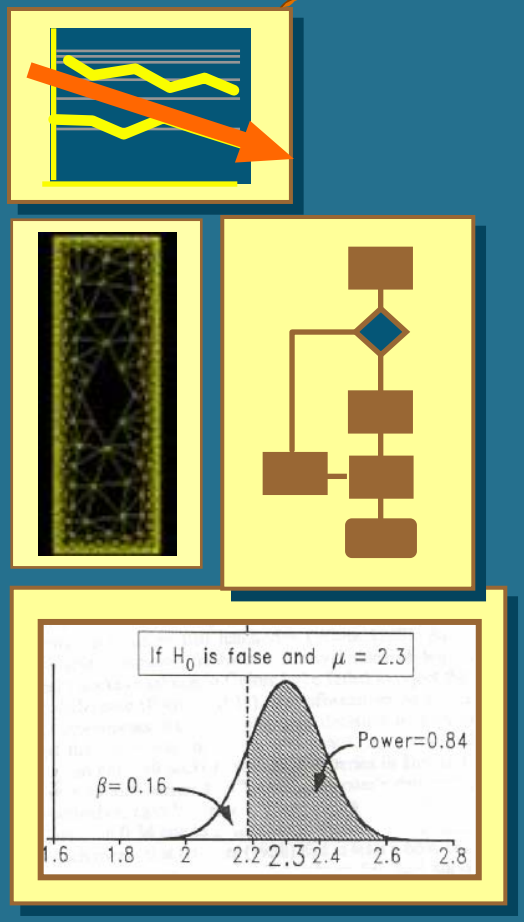



LTMO

# Choose LTMO Method

## LTMO Tools

- Statistical trend analysis
  - Linear Regression
  - Mann-Kendall
  - Sen's, Mann-Wilcoxon



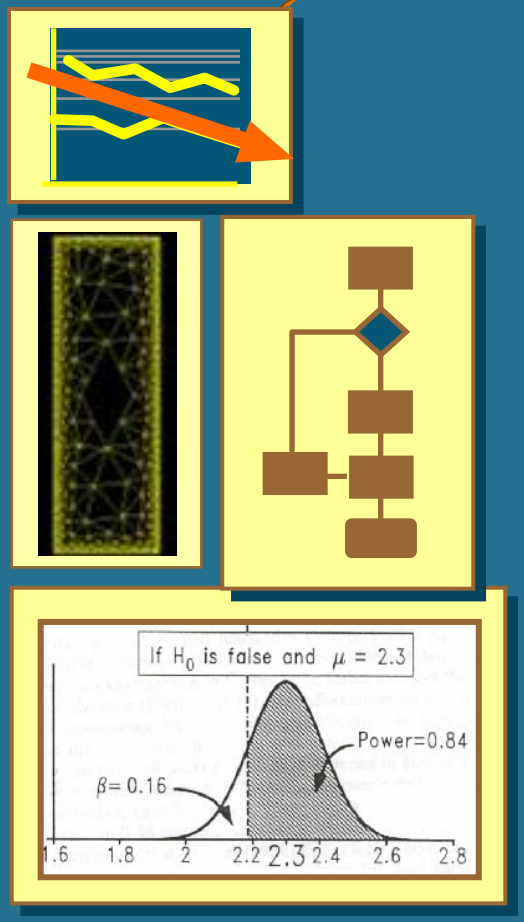



LTMO

# Choose LTMO Method

## LTMO Tools

- Statistical significance testing
  - Student's T-test
  - Sequential T-test
  - Power analysis



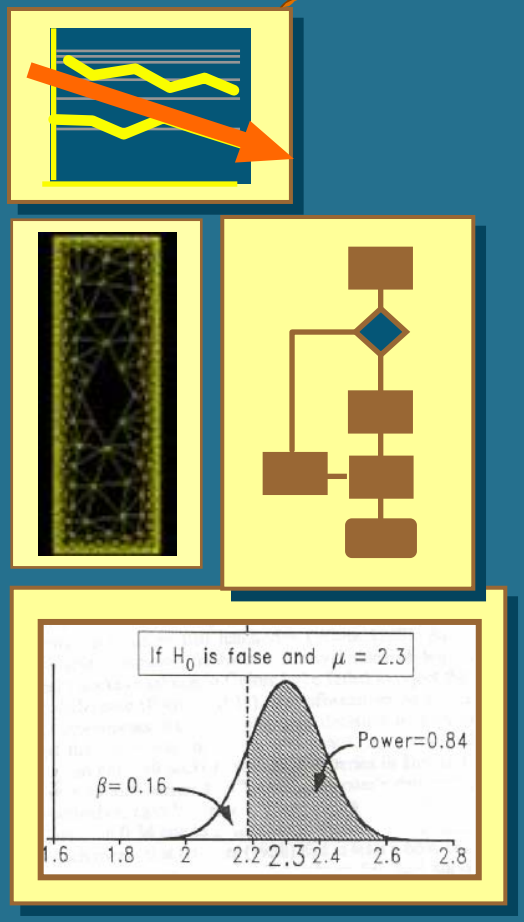



LTMO

# Choose LTMO Method

## LTMO Tools

- Interpolation
  - Kreiging
  - Delaunay method
  - Mesh creation






LTMO

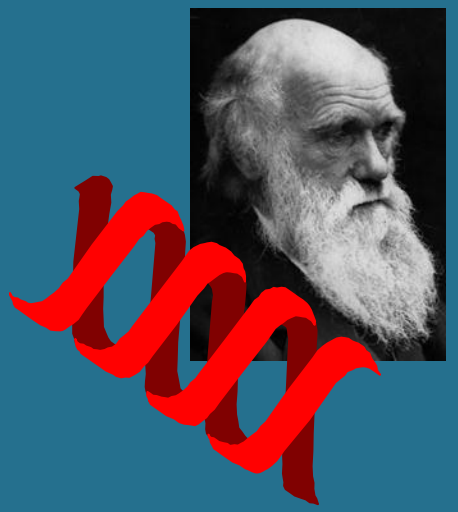
# Choose LTMO Method

## Mathematical Optimization

*Branch of computational science seeking a 'best' result for any question that can be answered by a numerical value.*

*Techniques:*

- *Simulated annealing*
- *Genetic algorithms*
- *Evolutionary strategies*



# Choose LTMO Method

## Mathematical Optimization

*Relatively new field (~1970's)*

*Computational and Programming challenges*

$$\begin{array}{lll} \text{minimize} & f(\mathbf{x}), & \mathbf{x} = (x_1, x_2, \ldots, x_n)^T \\ \text{subject to} & c_i(\mathbf{x}) = 0, & i = 1, 2, \ldots, m' \\ & c_i(\mathbf{x}) \geq 0, & i = m'+1, \ldots, m. \end{array}$$

***Key Terms*:**

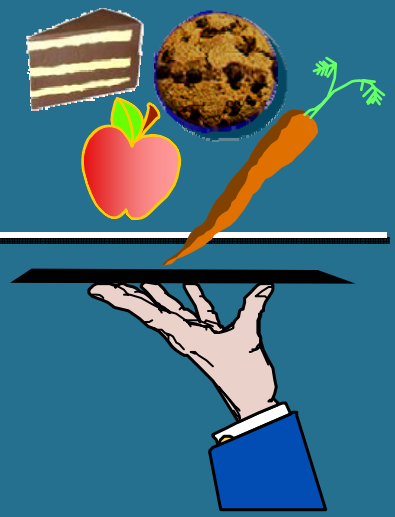
Objective Function – Value to be optimized
Decision Variables – Parameters subject to change
Constraints – Restrictions on allowed parameters

# Choose LTMO Method

## LTMO Methods

- Cost Effective Sampling
- Parsons Three Tiered
- MAROS (Monitoring and Remediation Optimization Software)
- GTS (Geostatistical Temporal/Spatial Optimization Algorithm)
- Mathematical Optimization Methods

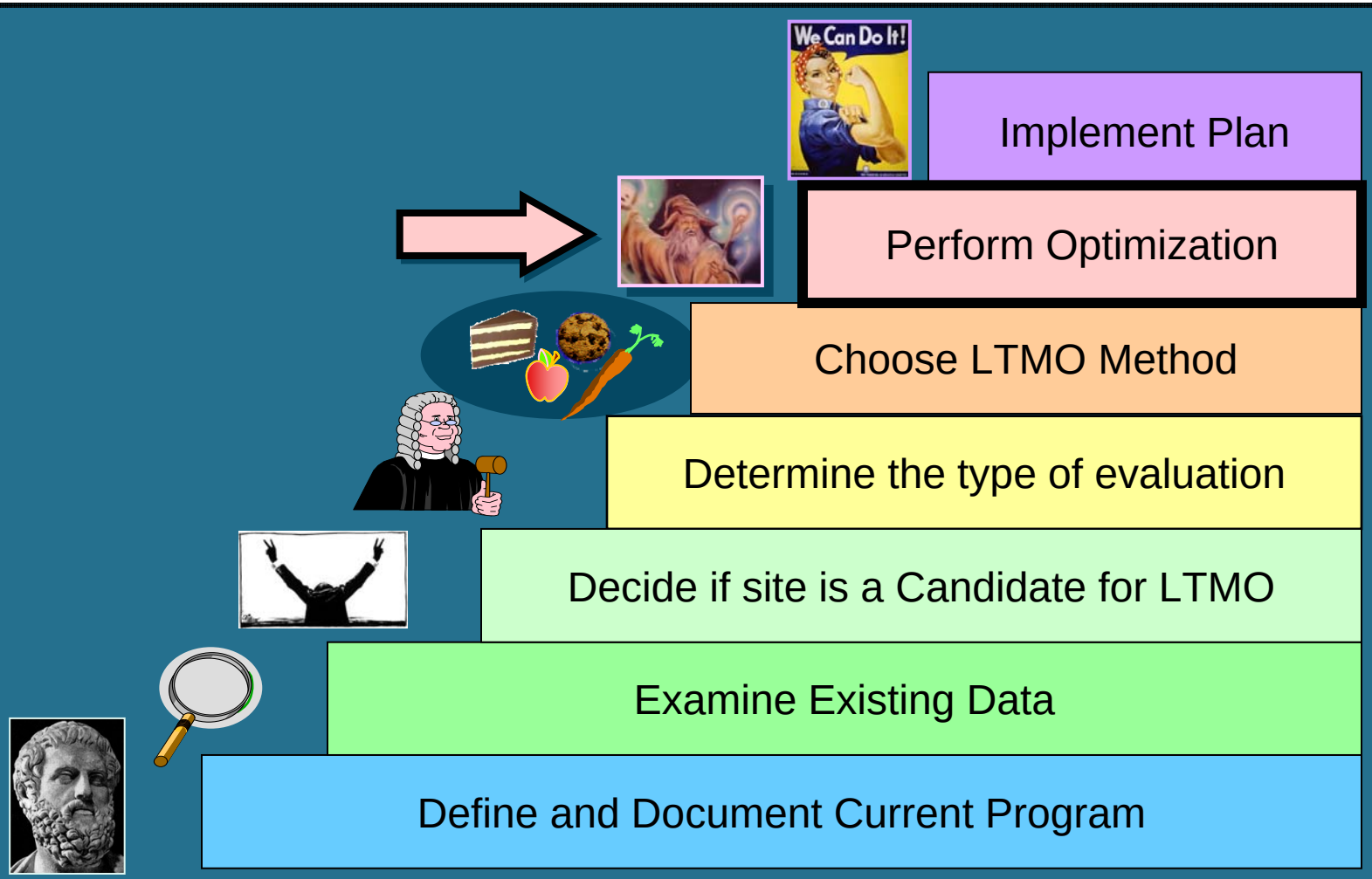
# Choose LTMO Method



## Summary

- Balance qualitative and quantitative methods
- Balance time, effort and cost with size, complexity, data and risk
- Guidance available
- Many tools and methods available

# 7 Steps of LTMO






LTMO

# Perform Optimization

## Expected Results

- Spatial – Locations
  - Remove wells from program
  - Addition of wells to characterize high uncertainty
- Temporal – Frequency
- Different results for different COCs
- Different results for different GW units



LTMO

# Perform Optimization

## Bonus Results

- Change in site conceptual model
- Change in monitoring objectives
- Change in sampling or analytical methods
- Evaluate effects of remediation activities



LTMO

# Perform Optimization

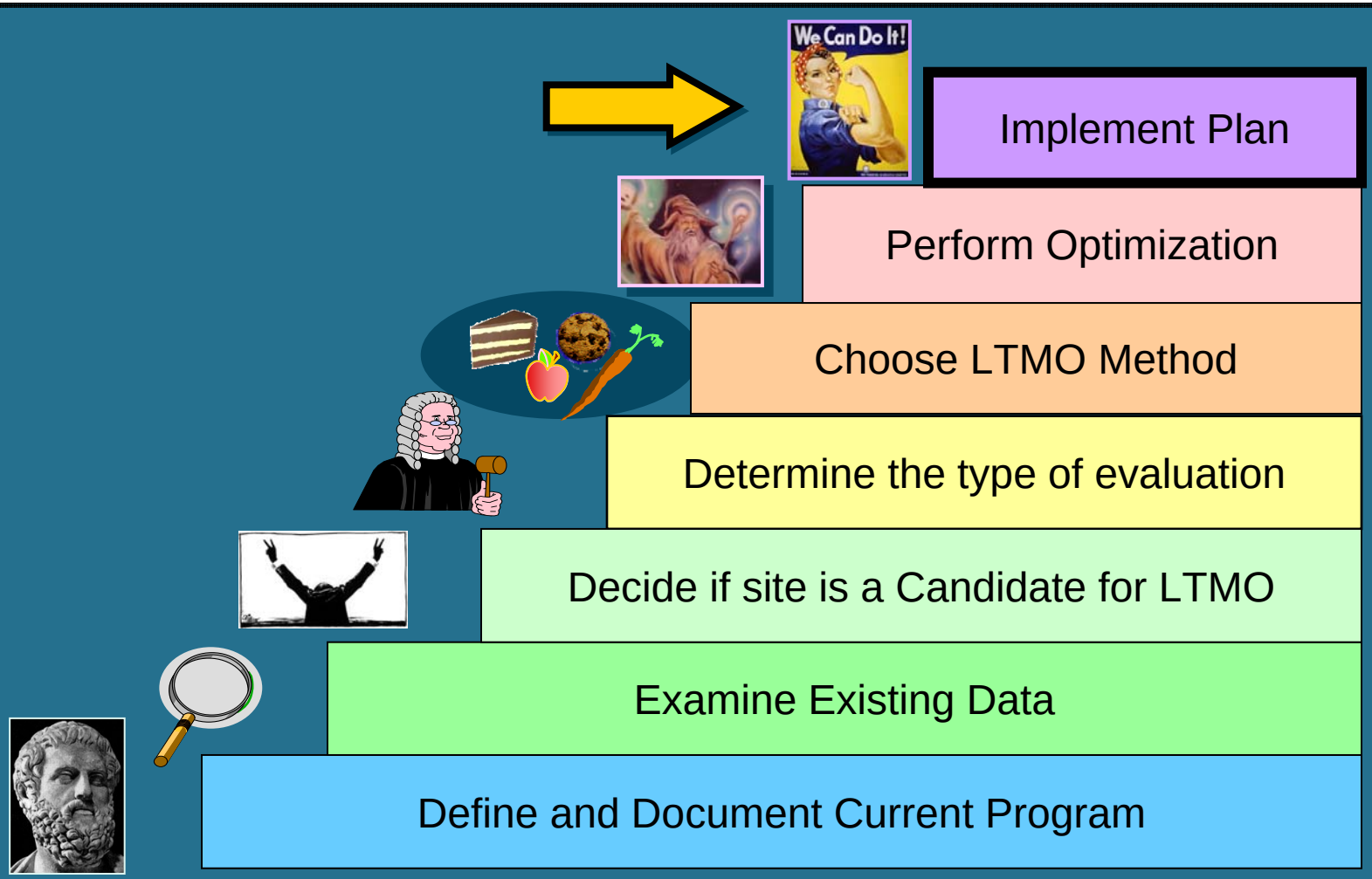
## Cost

- Small site, stakeholder agreement, uncomplicated hydrology and constituents
  - $2,500 - $5,000
- Larger site, stakeholder skepticism, uncomplicated hydrology
  - $5,000 - $15,000
- Larger site, stakeholder hostility, complicated hydrology, multiple units, legal issues
  - >$25,000



LTMO

# 7 Steps of LTMO



# Assess and Implement


## Assessment and Implementation

- Reality Check
- Compare with original monitoring program
- Compare across COCs
- Cost savings review
- Stakeholder review of recommendations



LTMO

# Assess and Implement


## Stakeholder Review

- Decision Document
  - LTMO Report
  - Response Action Completion Report
- Consistent with regulations and property use
- Modify SAP's, QAPP's, etc.
- Modify permits, and institutional controls.
- Vendor contracts/services



LTMO

# Assess and Implement


## Costs

- *Decision Document ($)*
- *Modification of documents ($$)*
- *Modify permits, and institutional controls ($$)*
- *Potential savings ~ $750 per sample*



LTMO

# Assess and Implement


**Review**

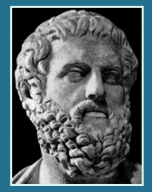
- *Flexible decision documents*
- *Periodic re-evaluation*
  - *Acquisition of statistically significant sample size*
  - *Change in well status (i.e. <MCL)*
- *Property transactions*

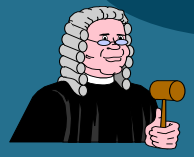


LTMO

# 7 Steps of LTMO

**Review**






Implement Plan

Perform Optimization

Choose LTMO Method

Determine the type of evaluation

Decide if site is a Candidate for LTMO

Examine Existing Data

Define and Document Current Program



LTMO